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WEATHER AND CROPS.

During nearly the entire month, temperatures were somewhat below the seasonal normal; in fact, with the single exception of 1898, the month was the coldest April in the last sixteen years. At Honolulu, the mean daily departure from the normal temperature was -1.7 degrees.

The rainfall was quite well distributed throughout the month; but there was considerable variation in the amounts received in the several localities. The average rainfall for the island of Hawaii was slightly less than that of the preceding month; while in the other islands the averages for April approximated the normal and were considerably greater than those of March. Considered by districts, the percentages of actual rainfall, as compared with the normal, were as follows: Hawaii—Hilo district, 60 per cent.; Hamakua district, variable, from 68 per cent. in the southern portion to 128 per cent. in the central and northern portions; Kohala district, variable, from 99 per cent. along the northern coast to 155 per cent. in the table land of the interior; Kona district, 77 per cent.; Kau district, 22 per cent.; Puna district, 50 per cent, (estimated). Maui—variable, from 50 per cent. in leeward and central sections to 100 per cent. or more to windward (estimated). Oahu—Koolauloa district, 94 per cent.; Koolaupoko district, variable, from 89 per cent. at Ahuimanu to 164 per cent. at Waimanalo; Honolulu district, 94 per cent., being greatest in the intermediate and upper levels; Ewa district, increasing from 20 per cent. along the leeward coast to 100 per cent. and over in the higher levels (estimated); Waianae district, 6 per cent. Kauai—Waimea district, 2 per cent.; Kona district, variable, from 33 per cent. at Makaweli to 91 per cent. at Koloa; Puna district, 162 per cent.; Northern districts, variable, from 47 per cent. at Kilauea to 75 per cent. at Hanalei.

Young cane made only fair progress during the month, its growth being checked to some extent in all portions of the Group by the cool weather and in certain leeward localities by lack of moisture. Damage by leaf-hopper was reported from sections of Hawaii and Kauai. The harvesting and milling of mature cane proceeded rapidly, the quality of the juice indicating that the crop of sugar would run considerably above the original estimates. Plowing and planting for the 1907 crop continued, but field operations were interfered with in portions of windward Hawaii by the excessively moist condition of the soil during the first and fourth weeks. Rice grew well, and by the close of the month had headed and begun to ripen in Oahu and portions of Hawaii; indications point to a good crop. Although the cool and cloudy weather retarded the growth of pineapples to a slight extent in some sections, on the whole the plants did very well and the fruit for the summer crop developed in a very satisfactory manner during the month. The showery weather brought out an exceptionally fine blossom on the coffee, and although high winds during the last week caused some damage to the blossoms in windward Oahu, prospects for a good crop are much brighter now than they were a month or two ago. Under the favorable weather conditions, pastures generally improved rapidly, and in consequence grazing stock was in much better condition by the close of the month. As had been anticipated, however, there was a considerable loss of cows and young calves that had been weakened by the previous drought. By the middle of the month barley had headed well, early peas, beans, squashes and pumpkins were bearing, and early peaches and figs were ripening. Early potatoes matured with a good yield.

FIELD EXPERIMENTS WITH SUGAR CANE.

By C. F. Eckart.

It may be safely stated that the majority of plantation managers, wherever sugar cane is grown, have at one time or another carried out practical tests in the field in an endeavor to ascertain the relative value of various agricultural practices. While many of these experiments have without doubt been productive of valuable results and have allowed the planter to realize increased profits through certain modifications of his methods, there can also be but little question that at times erroneous conclusions have been reached from field tests and contrary results have been obtained. The purpose of this article is to consider briefly a few of the more important points in connection with these practical investigations and to indicate some of the sources of error which may occasionally arise.

It stands to reason that in any comparison that may be drawn between field experiments bearing on the same line of investigation and conducted during different periods, varying conditions must continually arise which have a determinant influence on the final results. These changing conditions, while they can in many instances be readily recognized as potent factors in the modification of crop production, do not usually allow us any reliable means of measuring their relative effects. A large number of field tests bearing on the various agricultural practices, therefore, can only serve as indications of what may be expected from variations in the artificial conditions which we may impose, and only when numerous and repeated trials allow a somewhat safe average result to be struck as the basis for our conclusions. The question of *time* must needs be one of the most important points to be considered in forming an opinion as to the value of the results. It is true that a one crop experiment may at times allow one to safely draw deductions, but such instances are rare and the results obtained are usually such as follow radically different methods of treatment. If, for instance, we were to irrigate a measured area of a cane field with fresh water and a similar area with very salt water, it is needless to say that the greatly reduced yields in the latter case would indicate clearly that the saline irrigation was harmful. Should this experiment be carried out during good growing seasons and the yield of cane on the area irrigated with salt water fall considerably below that which had been obtained from fresh water, irrigation during unfavorable seasons, we should feel doubly positive that the brackish irrigation had affected the cane in a serious manner. The majority of comparative field tests, however, do not yield such wide variations in the weights of cane at harvesting time as would be found in the example mentioned. The smaller the difference in the production becomes, as manifested by the respective experiment areas, the less sure we are apt to feel that that difference was due to our changed treatment, and the less certain we should feel that this same difference would be maintained during a succeeding crop period. It becomes important then to repeat the experiments not only once but two or three times in order to feel fully justified in condemning one practice and extolling another.

In considering the modifying influences which tend to impair the results obtained during short periods, we will take a simple plat irrigation experiment as an example. Two plats which may be designated as A and B would be laid off in a field. As it is desired that the results to be derived from these plat experiments shall be indicative of the most economical use which may be made of the available irrigation supply, they must necessarily be subjected to the same conditions, so far as they may be obtained, with regard to the other agricultural practices, namely, the preparation of the land for planting, selection of seed cane, planting, cultivation, fertilization, etc., the only variation being in the amounts of water applied.

For A to B, then, to furnish data bearing *solely* on the relative production of sugar *as influenced by the different amounts of irrigation water applied* during the growth of the crop, the following conditions must be maintained:

Nature of the plats. The plats selected must be identical as regards area, depth, exposure, drainage, and the mechanical condition and chemical composition of the soil.

Preparation of the land for planting. Plowing and harrowing and the opening up of the furrows to receive the seed cuttings must be carried out in such a manner that the plats when ready for planting differ in no respect, however apparently trivial the variation, as regards drainage, depth of staple, and the mechanical condition and chemical composition of the staple and subsoil. In other words, the plats A and B must be identically alike.

Seed cane used in planting. Not only is it necessary that the same variety of cane should be used for supplying the planting material for the two plats in question, but the cuttings used in each case must be obtained from separate lots of cane of the same age and vigor and grown under precisely similar conditions. The cuttings must be of the same length, bearing an equal number of eyes and the eyes must have the same degree of vitality.

Treatment of plats. From the time the cuttings are placed in the ground, plats A and B must be subjected to the same conditions except with respect to the amounts of water applied. The canes must be stripped at the same time, fertilized with the same fertilizer and at the same time, and finally cut and weighed at the same time and their sugar contents tested by identically the same methods.

If it were possible to observe all the theoretical safeguards to accuracy as outlined above, the difference between the quantities of sugar obtained in the two cases would be due *to the difference between the conditions created* following a variation in the irrigation supply. It could not be entirely due to the separate amounts of water *available* to the canes in the two tests. If two inches of water were applied per week to A and three inches to B, a variety of conditions would arise which would in a measure influence the final results, conditions which though brought about by the difference in the volumes of water applied would at the same time impair such results as one might wish to reach with respect to the optimum amount of water required for the processes of cane growth. In fact, it is only possible through field tests to learn the effects on crop yields of the conditions created through the application of a certain practice during a certain period of crop growth. These conditions are naturally complicated and the relative potency of the separate influences cannot be determined. Their proportional effects may be represented by constantly varying factors which are never the same during corresponding periods in the development of successive crops.

If plat A were to receive two inches of water per week and plat B three inches, the soil in the latter experiment would be kept in a moister condition. This more moist condition could be responsible for a number of influences exerted on the growth of the cane. Fertilizing material of many kinds, when applied to B, would be more evenly and quickly distributed throughout its moister soil than would be the case with A. This more rapid distribution would mean a more ready assimilation, and consequently a quicker response to the stimulation would be manifested by the cane. Or the increased amount of water used in B could cause a greater loss through drainage of the more soluble elements of the soil, thereby altering the chemical composition of the plat and causing a variation in the conditions under which the tests were started.

The average content of salt (sodium chloride) in the irrigation waters of the Hawaiian Islands is about 30 grains to the U. S. gallon. If plats A and B in the experiments under consideration were irrigated with water of this saline strength, the former would receive approximately *6 2/3 tons* of salt and the latter *10 tons* during the growth of the crop. As it has been thoroughly proved that salt acts as an indirect fertilizer and unlocks stores of lime, magnesia, and potash from their insoluble compounds in the soil and renders these materials available to the cane, its influence on the growth of the crop must be a very material one. But when it is considered that our artesian waters not only contain sodium chloride in solution but also many other chemical compounds which may serve either directly or indirectly as food for the cane, we find that we are treating the crops on the separate test areas in a radically different manner as regards their fertilization in a broad sense of the term. Not only do we furnish plat B witb a larger amount of plant food, but by applying a greater amount of water, conditions are rendered favorable for a larger loss through drainage of the soil elements which were brought into solution in the saline medium. In like manner, changes would occur in the two plats with respect to their mechanical state, rate of nitrification, and other conditions.

It is thus seen that while one might be convinced at the conclusion of a one crop experiment, were it possible to carry it out in a theoretically perfect manner, that certain results were gained from employing certain agricultural methods, it would be impossible to measure the relative degree in which indirect influences were exerted on the production of the crop. The contention might readily arise that the main object of irrigation tests, given as an example above, was to learn the optimum amount of water for irrigation purposes, and that the weights of sugar obtained from the separate tests at time of harvesting yielded sufficient information for a reliable conclusion. In other words, these indirect influences should not be considered as being of any practical importance so long as they were induced through the varying amounts of water applied. It must be admitted that this argument would not be open to attack if our cane fields were subjected to identically the same conditions from crop to crop. The laws of nature, however, are opposed to such unalterable conditions and they are consequently never maintained. This causes us to consider the matter further.

Let us suppose that a repetition of the irrigation experiments A and B were made during the succeeding crop period. The land is carefully prepared as before, the cuttings are selected in the same manner, the fertilizer used is of the same formula and is applied at corresponding times of the year, and in fact, all of the conditions which may be artifically imposed are carefully brought to bear on the two plats of cane. The seasons, however, during which the second crop grows are materially different. A heavy rain falls shortly after the first application of fertilizer (which we will assume had a fair proportion of nitrogenous ingredients), and while the potash and phosphoric acid are firmly held by the soil, considerable nitrogen which had existed in the fertilizer as nitrate, or else had assumed that form in the soil, is washed away in the drainage from the two plats. Previous to the rainfall, plat B receiving an irrigation of three inches of water per week was in a more moist condition than plat A, which received only two inches of water per week, and on that account the drainage from its soil was greater than with A. Consequently more of the very soluble nitrogen was lost from the former plat than from the latter. Following the rain, then we may say, that A not only has a larger amount of the applied fertilizing material mixed with its soil, but also that its fertilizer is the better balanced of the two. Not only must the effect of the heavy rain be considered with relation to the applied fertilizer, but also in regard to the salt carried into the soil by the irrigation water and the accumulation of compounds rendered soluble through its displacing action. These accumulations would in large measure be washed from the land in the waters of discharge, and the proportions of soluble mineral ingredients in the soil water would become materially altered from those assumed at a corresponding period of the preceding crop.

Again, let us assume that for the first crop during the months of June, July, and August, very dry weather and high winds prevailed. The conditions during the corresponding periods of the second crop, we will say, were reversed, the air being humid and still with occasional showers of rain falling. In the former case, the drying effects of the winds during the period of maximum growth would doubtless give B a distinct advantage over A; in the latter case, the cane in A might find conditions more favorable than in B. Owing to the humid, still atmosphere and occasional showers, B might be kept too moist during the greater part of each interval between irrigations for the best results. The rate of nitrification in the separate tests could thus be brought to vary considerably and in a manner advantageous to A. These conditions and others which might be mentioned, when added together might give A the larger yield of sugar at harvesting time.

It may be considered by some that too much importance is being attached to these indirect influences, as we have called them, and that their effects on the development of the cane would only disturb the final results to an inappreciable extent. At this place it may be well, on that account, to consider this question in some detail and present figures showing the actual difference in weights of cane and sugar per acre which may arise from apparently trifling variations in the growth of the individual cane plants.

A large number of sticks were selected at random in a small patch of seed cane growing at the Experiment Station and the average length and weight of the internodes were accurately determined as follows:

Average weight of internodes.....	66.6	grams
Average length of internodes.....	2.42	inches
Average diameter of internodes...	1.34	inches

The average weight of one linear inch of the cane stalk was therefore 27.52 grams or .06 pounds. If we were to assume that at harvesting time the average stick of cane in a field were composed of 60 internodes of similar weight and dimensions, the length of the stalk would be 12 feet 1 inch, and the weight 8.809 pounds. Assuming that there were 15,000 canes to the acre, the yield of cane would be 132,135 pounds or 66 short tons, and the yield of sugar about one-eighth of this amount, or somewhat over 8 tons.

If each stick were increased in diameter by 1/1000 of an inch, the gain per acre in weight of cane would be 210 pounds. A difference of 1/100 of an inch in diameter would represent 1980 pounds of cane. Should the length and diameter of each joint be 1/100 of an inch greater than the dimensions of the internode, given as an example, the gain per acre in cane would be 2532 pounds.

If each stick were increased 1/32 of an inch in diameter, the yield of cane per acre would be increased by 6225 pounds, or over 3 tons. It is safe to assume that the most practiced eye could not discern a difference of 1/32 of an inch in the diameters of sticks of cane growing in the field. On our largest plantations this would make a difference of over 1000 tons of sugar.

From these figures it is readily seen that slight differences in the diameters of canes growing on comparative plats may make a considerable variation in the acre yields. It is also readily understood that these seemingly trivial differences in dimensions may be caused by conditions, the existence of which might easily be beyond our powers of perception.

When field tests with sugar cane are carried out on a plantation, the idea naturally is to gain information as to the best agricultural methods to employ for succeeding crops. These succeeding crops are to be grown under a variety of conditions and on that account a one-crop experiment may readily fall far short of yielding the information desired. The one crop test would not necessarily be conducted under the normal climatic conditions of the plantations. Again, certain modifications in agricultural practices might give us, for one crop, a distinct gain in yields over those obtained from the customary methods employed, although in the long run the advantage would not hold good owing to the greater draughts made in the start upon the store of plant food in the soil. It becomes important, therefore, to carry out such field experiments as are contemplated for a *number of crops.*

As the conditions of soil and climate are not uniform over many of the Hawaiian plantations, it would also be of a distinct advantage to conduct the tests in as many localities on the plantation as the areas subjected to different conditions would warrant. It would be found in many instances that while certain fields would be benefitted by one treatment, other fields would profit more from a different practice. Furthermore, the sites chosen for the field experiments should be such as compare closely with large areas.

The piece of ground selected for the experiment field should not only be as uniform as possible in the nature and depth of its soil, but should be free from all hollows and ridges, so that when divided up into smaller plats, each subdivision would be characterized by the same conditions of drainage and exposure. The past history of the various plats should be the same, in order that one may feel assured that any differences in yields which might be obtained from the comparative tests was not influenced by differences in the previous treatment of the subdivisions before converting them into parts of a small experiment station.

The preparation of the field for planting should be under-taken with the greatest care in order that irregularities in the depth and thoroughness of plowing may be avoided as far as practicable. One piece of ground plowed and harrowed in a more thorough manner than another might give us the additional 1/100 of an inch in the diameter of the cane, which we have seen might cause a variation in the final weights of almost a ton. We are assuming now that the experiments to be conducted are not such as bear upon the question of plowing, but on one of the other agricultural practices, fertilization for instance. As far as it is possible, the same conditions except those pertaining to the use of fertilizers must be imposed upon all of the plats in the experiment area. Plowing, harrowing, opening up of the furrows, and planting must be carried out in precisely the same manner. Inability to get the land of the separate plats into identically the same condition only emphasises the necessity of repeating the experiments.

The seed cane should be obtained from the same locality and represent cuttings of the same age and vigor. To insure uniformity in the nature of the seed, the cuttings should be well mixed after an adequate number have been prepared, and divided into as many equal piles as there are plats to be planted out. They should either be of uniform length or else bear an equal number of eyes.

From the time the land is prepared for planting until the harvesting and weighing of the cane, each agricultural practice must be carried out in as nearly the same manner on the separate areas as practical methods will permit. At the conclusion of the experiments, the cane on the respective plats should be weighed and the quality of the juice in the average canes determined. The eye in most instances is incapable of properly estimating the relative value of the separate treatments as shown by the stands of cane.

In all investigations of this character, it is of course necessary to plant out a certain area as a check on the plat experiments. The best check with experiments dealing with varieties of cane would naturally be a plat planted out with the standard cane of the district in which the tests are being conducted. All introduced varieties could then be compared with the standard cane. With fertilizer experiments, an unfertilized area would serve as a basis for comparison, and so on.

The following diagram will serve as an illustration of the manner in which a small experiment field (of nearly two acres area) could be laid out to best advantage. The plan presented is that which is being followed by this Experiment Station in establishing substations on a number of unirrigated plantations for considering the effects of various fertilizer ingredients on different types of soil.

The field is 310 feet long by 270 feet wide. This area is divided into thirty-six plats of six rows each. The plats are grouped into four divisions: A, B, C, and D. Each division is 270 feet long by 70 feet wide, and contains nine plats. The rows, of which there are six in each plat, are 5 feet apart. The space allowed between adjoining divisions is 10 feet wide.

The treatment of the respective plats on these substations, dealing with fertilization, is as follows:

Divisions A and C are the areas to be fertilized, B and D being left unfertilized as checks. The fertilizer is to be applied in two applications, the total quantities for the different plats in A and C being for

Plat.	Fertilization.		
1	Nitrogen, 60 lbs.;	Potash, 60 lbs.;	Phos. Acid, 60 lbs.
2	Nitrogen, 60 lbs.;	Potash, 60 lbs.;	Phos. Acid, 90 lbs.
3	Nitrogen, 60 lbs.;	Potash, 90 lbs.;	Phos. Acid, 60 lbs.
4	Nitrogen, 90 lbs.;	Potash, 60 lbs.;	Phos. Acid, 60 lbs.
5	Nitrogen, 90 lbs.;	Potash, 90 lbs.;	Phos. Acid, 60 lbs.
6	Nitrogen, 90 lbs.;	Potash, 60 lbs.;	Phos. Acid, 90 lbs.
7	Nitrogen, 60 lbs.;	Potash, 90 lbs.;	Phos. Acid, 90 lbs.
8	Nitrogen, 90 lbs.;	Potash, 90 lbs.;	Phos. Acid, 90 lbs.
9	Nitrogen, 60 lbs.;	Potash, 60 lbs.;	Phos. Acid, none

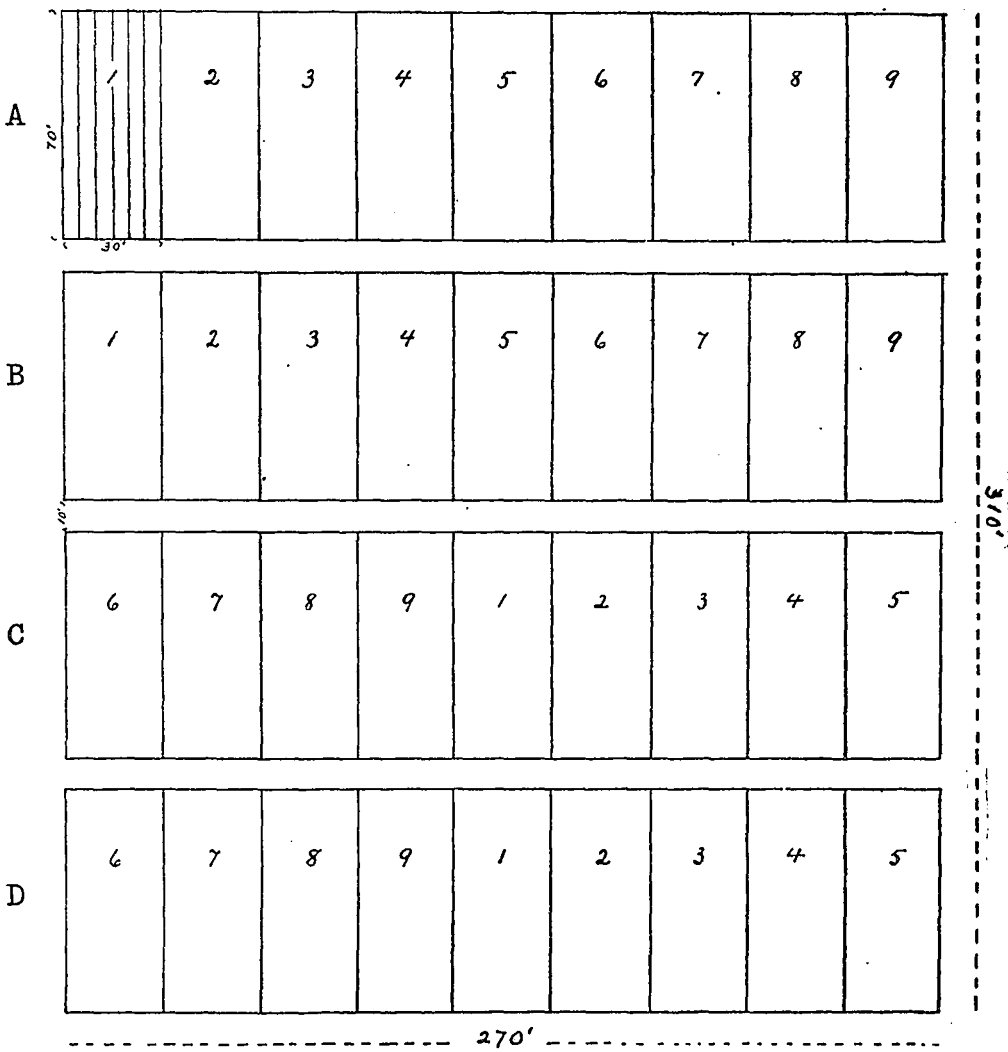
The plats in divisions A, B, C and D are to be treated identically alike, the general plantation methods being employed in caring for the same, except in regard to fertilization, irrigation and the selection and planting of seed. In this latter particular, care is to be observed that the cuttings are to be of the same length or bear the same number of eyes. They are to be taken from the same lot of seed cane and after thorough mixing divided into thirty-six equal lots from each of which one plat is to be planted. It is necessary that the nature of treatment to which the subdivisions of the field are subjected and the date of treatment be carefully recorded. At time of harvesting the middle two rows of each plat are weighed in order to furnish comparative data as regards yields.

It will be noticed that for each plat in Divisions A and C there is a corresponding plat in Divisions B and D which is left unfertilized for comparison. The order of the plats in C and D is also different from that in A and B.

At the conclusion of the tests, therefore, a duplicate series of results will be furnished bearing on the effects of the varying amounts of fertilizer ingredients applied. An average can then be taken of the yields of plats which have received the same treatment and a safe comparison made with the others.

In carrying out a series of comparative tests on an *irrigated* plantation, one of the first considerations, naturally, is the even distribution of water over the experiment area. Unless

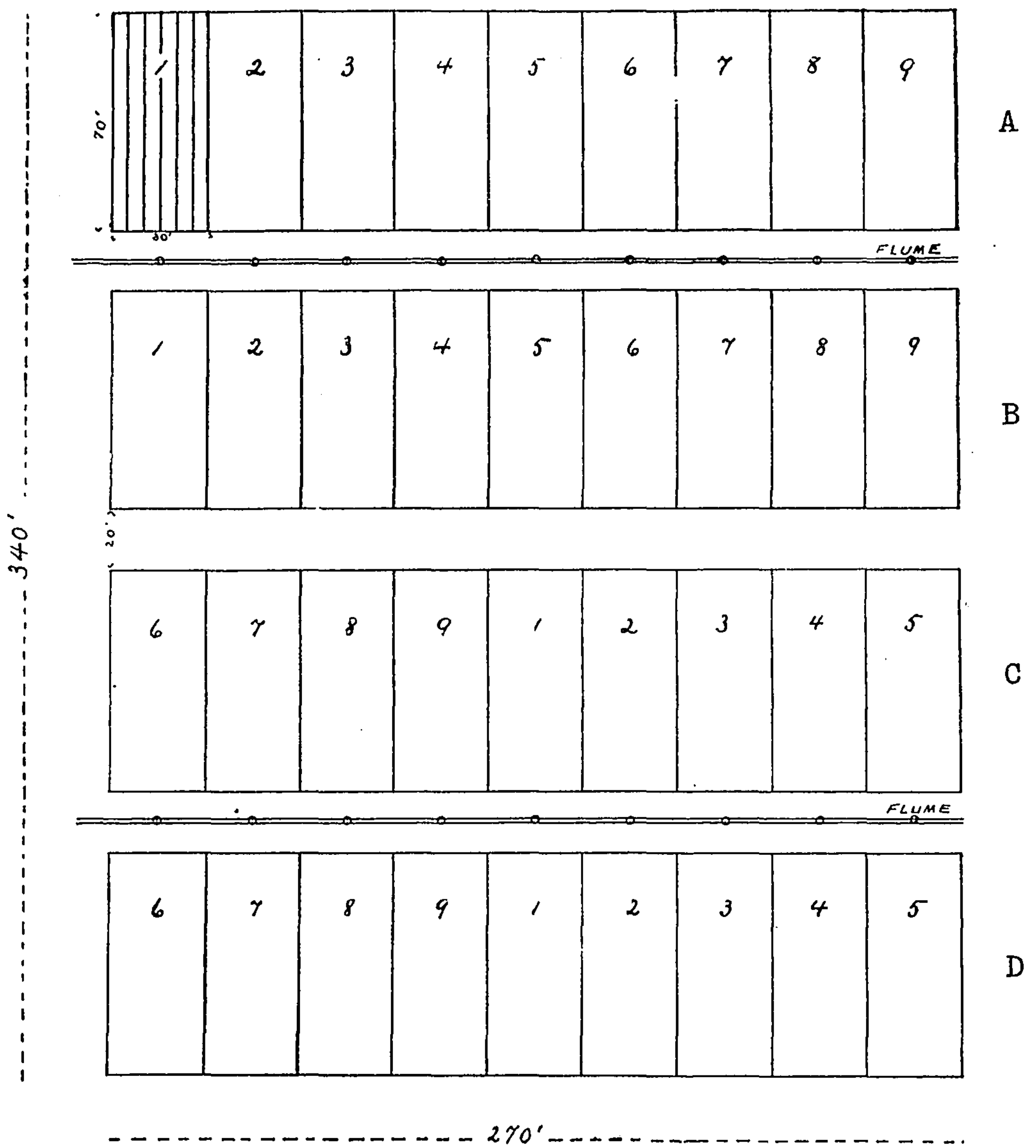
PLAN OF UNIRRIGATED SUBSTATION.



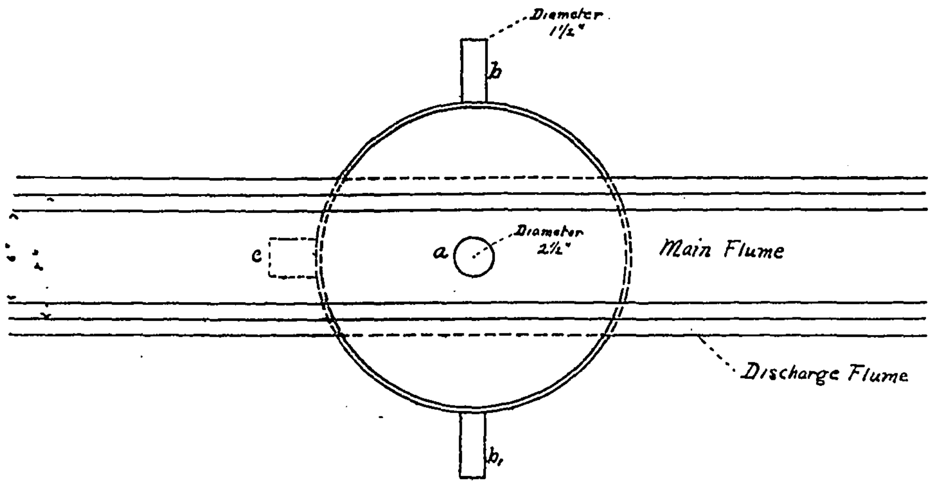
this is obtained, results bearing on fertilization or other practices are very apt to prove of little or no value, for the reason that differences in yields among the plats could be caused in large measure by differences in irrigation. In fact, the different volumes of water applied to the test area might readily influence the growth of the cane more, in some instances, than the application of different kinds or different amounts of fertilizer. In growing a number of varieties of cane in competition with each other, the manager of an unirrigated plantation has less to contend with in obtaining uniformity of conditions than the manager of an irrigated estate. Should the latter, through any mischance, allow one variety of cane to receive more irrigation water than the others, he might readily be lead into the mistaken opinion that the variety in question was the most suitable cane for his soil and climatic conditions, because in yields it surpassed a number of other varieties which had been less favored with respect to the artificial conditions which he imposed.

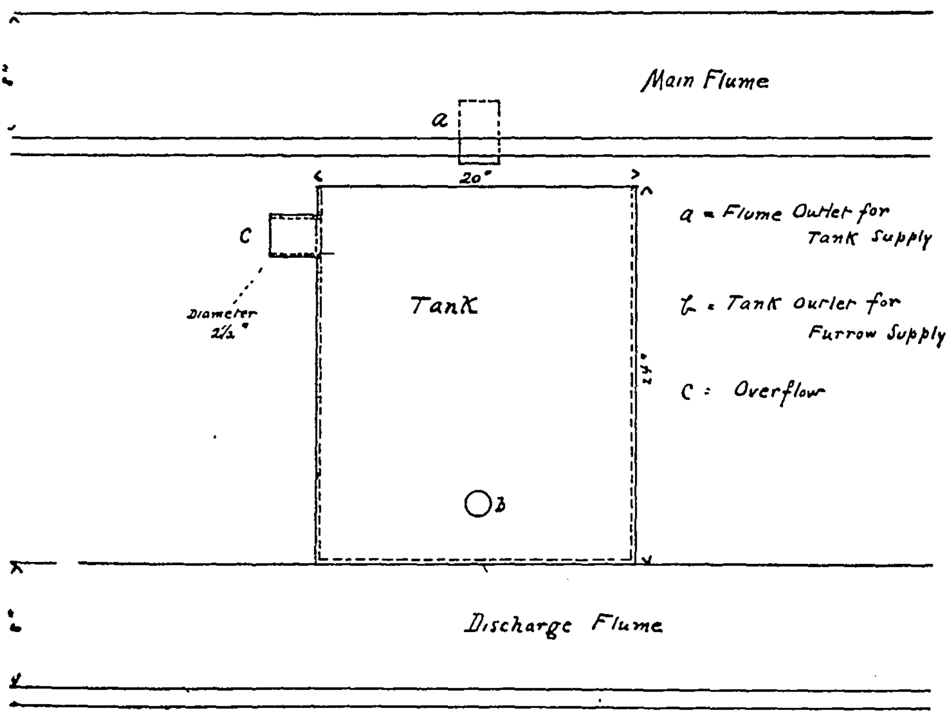
In laying out experiment areas on irrigated plantations for conducting the same series of fertilizer experiments, as has been described with reference to the unirrigated estates, the following method was adopted by the Experiment Station as being one of the most practicable plans to follow. The arrangement of the plats and divisions is identically the same as in the first instance, except that between the respective divisions there is a strip of unplanted ground twenty (20) feet wide instead of ten (10) feet. The distribution of irrigation water is effected as follows: Two flumes are required to run along the strip of ground between divisions A and B, and two other flumes along the strip between C and D. The upper flume, as shown in the accompanying diagram, carries the supply of water, the lower one being a discharge flume. A tank 24 inches high by 20 inches wide is placed between the two flumes in such a way that by drawing out a plug, a, in the main or supply flume, it may be filled with water up to the overflow outlet. As the water begins to run into the tank from the supply flume, it will run out of the tank through outlets b and bl, on either side through sections of hose connecting with two corresponding plats (fertilized and unfertilized). The openings, b and bl, are 1½ inches in diameter, while the supply flume outlet, a, is 2½ inches in diameter. This difference between the diameter of the supply opening and that of the tank outlets will naturally cause the water to rise in the tank until it reaches the overflow outlet, e, from which it will run into the discharge flume and keep the water in the tank at an uniform head. The supply flume and discharge flume may unite beyond the border of the substation and the water run off into any desirable channel. It is, of course, necessary that some caution be observed in that the sections

PLAN OF IRRIGATED SUBSTATION.



PLAN OF TANK AND FLUMES FOR IRRIGATED SUBSTATION.





of hose connecting the tank with the furrows shall be of the same length and when in use that the section connected with b, for instance, is allowed to lie about as straight upon the ground as that connected with b-1, in order that the friction encountered by the water in passing through one piece of hose will be approximately the same as that for the water passing through the other.

The above description of the irrigation system applies, of course, only to the substation proper. The question of getting the water up to a height of three or more feet when it enters the substation area, is one to be solved according to the conditions of the individual plantation and the location of its substation.

It might be well at this place to say a few words concerning the nature of the investigations which are being started this year by the Experiment Station in connection with substation work. The series of tests described will be carried out on about eight plantations and will deal with the effects of the various fertilizer ingredients on different types of soil. Next year it is proposed to start a second series of tests on eight other representative areas to learn the most economical amount of fertilizing material to apply for maximum yields. Considering the fact that the fertilizer bill for the islands amounts to about $2,000,000 annually, it is believed that too much importance cannot be attached to systematic investigations of this nature. Naturally there are a great many other agricultural questions with which substations will ultimately deal, but it was deemed advisable in beginning this new line of work to take up the subject concerning which there is probably more speculation and less definite knowledge than pertains to any other dealing with the growth and development of the sugar cane. We all know that fertilizers pay and that good returns result from money invested in such material. The fact remains, however, that much is yet to be learned concerning the most economical use of fertilizers in giving us a maximum growth of cane.

The yields of cane obtained from the series of fertilizer experiments mentioned will be supplemented with data obtained from a thorough analysis of the soils on which the various experiments are carried out. By conducting the same experiments under a number of different conditions, a valuable comparison may finally be drawn with respect to the influence of the various fertilizer ingredients on the several soil types, and the information gained after a continuation of the tests for a number of years can be applied to advantage, in a general way, to many plantations. If each substation dealt with a separate agricultural problem, the results obtained, while they would be of benefit to the plantation conducting the tests, would in most particulars offer inadequate information to plantations subjected to other conditions. The fact that sugar is "made" in the field and that certain modifications in agricultural practices may be productive of material gains in the yield, should serve to stimulate practical investigations with this end in view. If each plantation on the islands started a few experiments during each crop period on representative areas of its estate and carefully carried them out in accordance with correct principles for a number of years, it is safe to say that the total output of sugar for the islands would be considerably increased.

THE MANUFACTURE OF SUGAR IN THE COLONIES.

Since the abolition of bounties on beet sugar in Europe there has been much discussion as to which of the two industries, cane or beet, will obtain supremacy in the world's markets. At a recent meeting of German fabricants, Prof. E. O. Von Lippmann, of Halle-on-Saale, delivered an interesting survey of the conditions of sugar production in the colonies.

He commenced by saying that little information exists as to the economic situation of the colonies outside English and French journals. Only two years ago it was supposed that the colonies made enormous profits even when the price of sugar was 6 marks per quintal (15 francs per 100 kilos.), but today we know that this is not so. Passing in review that various centres of cane sugar production, the savant first referred to Egypt, where the sugar cane thrives well, and contains as much as 12% of sugar. The raw sugar factories are perfectly equipped, and a large refinery also exists in this country. Egyptian sugar is mainly shipped to the East Indies, Russian crystallized sugar being imported for consumption, and obtainable below the net cost of production owing to heavy bounties, which, on the other hand, exclude it from British India. The sugar industry in Egypt will extend greatly in the immediate future, benefiting by the irrigation works of French and English companies.

In Natal, as in East Africa (Pangani), the manufacture of sugar has extended but little.

In Mauritius and Reunion, the industry still remains at a very low level, notwithstanding the efforts of eminent agriculturists, such as Boname. The effect of the bounties has been to encourage the old routine.

In British India, the native land of the sugar cane, the industry assumes rather a domestic character, palm sugar being also manufactured. The East Indies produce annually two million tons of sugar, but the methods of manufacture are most primitive. This output does not suffice for the local demand, so that sugar is imported from Egypt, Mauritius, Reunion, and even from Germany and Austria.

The Indian Hinterland and the Strait Settlements produce a notable quantity of sugar, but by methods as primitive as in India. So also in China, where little is known about the skill in production. In Japan the cane is only cultivated in the south, and the sugar industry dates from the annexation of Formosa.

In Java, on the contrary, the co-operation of scientists, the establishment of experimental stations, and the wise support of the government, have raised the sugar industry to a state of great perfection. The cultivation of the cane in this island is nevertheless limited by the necessity of producing rice, which constitutes an indispensable food of the native population which is steadily increasing. Last year, Java produced more than a million tons of sugar, but the cost of production being somewhat high, the manufacture of sugar has not been very remunerative during recent years.

In Australia, Queensland possesses a well established industry, but the cultivation of the cane is costly and consequently restricted. New Caledonia and New Guinea scarcely count. The Fiji Islands produce more, and their production might be increased if sufficient capital were available. As regards the Sandwich Islands, Hawaii is well to the front; and her 58 factories have produced 400,000 tons of sugar during recent years. But the manufacture is only remunerative since her produce has been admitted free to the markets of the United States; and, on the other hand, the cane is seriously threatened by an insect pest, of Australian origin, which has not yet been successfully exterminated.

In North America, notwithstanding heavy protection, Louisiana alone deserves mention as a sugar producer of secondary importance. In Mexico, the industry might be developed, but is at present in a primitive state. In South America, Peru, Equador, northern Chili, and the Argentine, the cane sugar industry is of more or less importance, although little developed from a technical point of view, and mainly supplies the local markets. Similarly with Venezuela and Brazil, where, notwithstanding government assistance, the progress of the industry is very slow. These countries suffer especially from want of labor.

Among the islands of Central America, Cuba is the most important, the manufacture of sugar having already attained a relatively high degree of perfection and promising considerable extension by the aid of American capital, and more especially if manual labor can be more largely dispensed with.

The production for this year is said to amount to 1,400,000 tons.

In Porto Rico modern usines have been erected by French and American capitalists, and the industry enjoys protection raised by American tariffs.

Finally, in the English and French West Indies, the sugar industry is still very backward, notwithstanding the efforts of agriculturists and eminent experts. Considering their high cost of production, the West Indian estates must be materially improved if they are to subsist and develop.

Dr. Von Lippmann hence concludes that great changes and improvements are needed in the Colonies, and that it is essentially necessary to remedy the deficiencies in labor and capital prevailing in these countries if they are to be placed in a position to seriously compete with the European beet industry. Moreover, low prices constitute our most valuable auxiliary in the struggle with cane sugar. The best proof of this being that, since the great rise in prices in October last, the sugar industry of all Colonial countries displayed extraordinary activity with a view to increasing their production.

If the latest estimates are correct, the deficit in the production of Europe is 21%, but the price has increased 75%. This increase of 75% has given an immense impetus to the Colonial industry, which leads us to the following remarks. The cane is not an annual, but a plant which gives several crops; consequently, as soon as new plantations have been planted up the ratooning of the cane is assured for a long series of years. When once capital is invested in the colonial industry—and with the present high prices this should be easier than in the past—factories will remain in operation whether they yield a profit or not. This is not a very cheerful prospect for beet.

Hence, the excessively high prices of sugar, agreeable as they may be to each of us at the present moment, are a great misfortune for foreign markets as well as for our own, where they comprise the normal development of consumption and threaten, by the subsequent reduction of receipts, to furnish the government with one more motive for delaying the reduction of the duty on sugar. We have therefore good reason for following, step by step, the development of the Colonial industry.

This account by the German savant was fully appreciated by those present. It will, indeed, be desirable for the European industry to closely watch the economic evolution of its rival under the influence of new conditions brought about by the abolition of bounties and the rise in the price of sugar. —From Journal des Fabricants de Sucre.

IRRIGATION IN HAWAII.

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*By Walter Maxwell, Ph. D.

INTRODUCTION.

The precipitation of atmospheric moisture is very uneven and irregular over the surface of the earth. There are zones that are marked by annual deluges, and there are vast areas upon which rain rarely falls. These rainless areas are not confined to conditions peculiar to specific latitudes, but are found in the tropical regions of India and Africa, over the wide plateaus of North America, and in other localities having widely varying climatic conditions.

The regions of small rainfall are very generally distinguished by lands of great natural fertility. This is due largely, on the one hand, to the absence of great rains that leach out the elements that feed plants, and, on the other hand, to the relative absence of crops, which results from lack of rain. Among the most productive tracts upon the earth today are regions that were naturally arid, but which have been rendered productive by irrigation. These tracts include the Punjab and other vast districts of India, the great basin of the Nile in Africa, and large semiarid areas that have more recently been brought under cultivation in the middle and western United States.

The failure of the natural rainfall to produce crops may be due to the insufficiency of the total precipitation, as in regions in India, Africa, and other lands, where it does not aggregate 10 inches per year; or it may be due to the seasonal distribution, as in other parts of India and Africa, in northern Queensland, and some of the Pacific islands, where a heavy and almost the whole precipitation takes place within two or three months. In speaking of the agriculture in parts of the Himalayas, Mr. Buckley[1] says: "Where the rainfall varies from 50 to as many as 100 inches in the year, crops grown on the terraces in the mountains are matured in the dry season by artificial irrigation." In some localities in northern Queensland the annual rainfall reaches and exceeds 100 inches, yet the sugar cane crop has to linger through an annual arid

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[1] Irrigation Works in India and Egypt, R. B. Buckley. London, 1893, p. 1.

*Dr. Maxwell was for a number of years director of the Experiment Station of the Hawaiian Sugar Planters' Association, and this article was prepared in connection with irrigation investigations of the U. S. Department of Agriculture, and issued as a bulletin of the office of Experiment Station of the Department.

period which greatly reduces the yield, while upon the Pacific islands of Hawaii, despite the winter rains, many of the most fertile lands would be useless without the prevailing practice of irrigation. Irrigation, consequently, is playing an increasingly important part in modern intensive agriculture.

The history of irrigation covers methods of applying water to crops, including the crudest efforts of the peasant and the great systems executed by governments or corporations, such as are in operation in India, the United States, and in the valley of the Nile. Certain of those systems are vast, and have been instituted under the pressure of meeting great emergencies. Today India is using irrigation upon a stupendous scale in grappling with the calamity of famine.

Economic irrigation requires the consideration of physical laws which were unknown to the authors of primitive methods, and which have not been generally observed in establishing the huge systems of irrigation already mentioned. Some of the physical laws which underlie any rational practice in the application of water to crops are briefly considered in the following paper.

EVAPORATION OF MOISTURE FROM WATER SURFACES AND SOILS.

The movement of moisture is constantly going on. The simplest evidence of this movement is seen in rainfall and in the evaporation from water and soil surfaces.

The factors that have been given the greatest prominence as exercising a controlling action upon evaporation from soil and from the surface of water are the temperature and the relative humidity of the air. This view is amply sustained if the examination is confined to the action of these factors during the extreme seasons of the year. There is no question concerning the greater evaporation of moisture from soils and waters during the months of summer, when temperatures are high, and the amount of atmospheric moisture is also relatively smaller than during the cold season, when the temperature is lower and the humidity of the air greater. This is demonstrated in many localities by the excess of water that accumulates within and upon the soil in winter and the droughts that obtain in the summer. There are localities and regions, however, that are so fortunate as to have the greatest rainfall during the season of greatest evaporation and consequently of greatest plant growth.. Setting aside the differences concurrent with the seasons and confining observations to the relative actions of the several factors during the months of summer, it is then found that the temperature of the air and the amount of moisture that it contains are not the most dominant factors in the control of evaporation. As already said, they are factors, but their combined effects do not compare with the effects of wind. Not only in the matter of irrigation, but also in the location and exposure of reservoirs this fact is of leading importance. In view of this the writer carried out a series of evaporation determinations by means of evaporators, at the same time keeping a record of the temperature and relative humidity of the air. These observations were made as a part of a study of the factors that control the rational irrigation of the sugar cane on the Hawaiian Islands. The form of evaporator used was a small galvanized iron pan, 1½ inches deep and having a superficial area of 120 square inches. The evaporator was placed under the covered stand where the meteorological instruments were located and between the dry and wet bulb thermometers, thus having the same protection from the sun and the same exposure to the wind as those instruments. At 7 o'clock on the morning of the first day 500 grams of water were weighed into the evaporator, and at the end of each twenty-four hours the weight was retaken and recorded and the volume made up again to 500 grams. These observations were made daily throughout one year. A second evaporator similar to the first was placed in a barn 30 feet distant from the other. The large doors of the barn were kept open day and night to allow of air circulation, but any violent air movement was rigidly guarded against. The purpose was to secure the same conditions of temperature and humidity of the air as those surrounding the evaporator placed outdoors, but to eliminate the factor of wind. The data furnished by the two evaporators were taken and recorded in the same manner and with the corresponding readings of the thermometers. The results of these observations, covering a period of two hundred and seventy days, reduced to monthly averages, are given in the following table:

Relative evaporation from water surface exposed to the wind and protected from the wind.

Month.	Exposed to the wind. Temperature of air.	Humidity of air.	Evaporation.	Protected from the wind. Temperature of air.	Humidity of air.	Evaporation.
	°F.	Per ct.	Per ct.	°F.	Per ct.	Per ct.
April	74.4	77.4	28.5	78.7	77.4	11.7
May	76.0	80.2	27.2	80.3	80.2	11.3
June	77.0	83.6	22.5	81.3	83.6	10.1
July	78.3	77.3	25.8	83.0	77.3	12.1
August	78.7	73.8	30.0	82.4	73.8	12.5
September ..	76.8	80.4	24.3	80.6	80.4	10.0
October	75.3	80.1	23.5	78.8	80.1	9.2
November ..	71.0	83.2	23.3	74.1	83.2	9.4
Average ..	75.9	79.5	25.6	79.9	79.5	10.8

A relation may be noted between the temperature and humidity of the air and the amounts of water evaporated, but the important fact revealed by the table is the constant and great difference in the amount of water evaporated from the two pans. The total amounts of water lost during the eight months by the exposed and protected evaporators were, respectively, 33,480 grams and 14,175 grams.

The outdoor evaporator lost 136 per cent. more water than the indoor evaporator. This vast difference is wholly due to the action of the wind, to which the former was exposed, and it occurred in spite of the fact that the indoor temperature was uniformly 4 degrees higher than the outdoor temperature.

The differences in the amounts of water given off by the outdoor evaporator on different days bear some relation to the differences in the temperature and humidity of the air. They are too great, however, to be accounted for by those factors alone; they were, in fact, largely due to different velocities of the wind. By way of proving this, we make use of the data recorded during the month of November. During the first ten days of that month the average daily evaporation, under the constant action of the northeast trade wind, was 33.7 per cent. During the following eight days, when the wind direction was south and the air was almost still, the average evaporation was only 13.2 per cent. During these eighteen days the maximum evaporation under a very high wind reached 41.2 per cent., while upon another day, no motion of the air being observed, the evaporation was only 8.1 per cent. In the course of these twenty days the temperature variations were very small.

From the determinations that have been recorded it may be seen that the movement of the air is the paramount factor in controlling the rate of evaporation from water and soil surfaces. Soils whose surfaces are exposed to the action of strong driving winds will give up more moisture, and will therefore need more water, than areas in sheltered locations. Water surfaces exposed to the sweep of the wind lose heavily by evaporation. Economy of water therefore dictates that reservoirs be built so as to have the greatest depth and the least surface, and that they be located so as to be sheltered from the direct action of prevailing strong winds.

TRANSPIRATION OF MOISTURE BY VEGETATION.

The volume of water evaporated from the soil and the volume transpired by the plant during its growth are the controlling factors in determining the total water required in the production of a crop, and therefore the quantity of water to be supplied by irrigation.

Water enters very largely into the structure of all living organisms. It is not only the agent which makes possible the mobility of other constituents of the plant, conveying them from one location to another, but it enters in large proportion into the structure of the organism itself. Consequently plants and trees at all times hold a great volume of water, the supply of which is constantly replenished by the water taken up by the roots and as constantly depleted by the moisture given off into the air by means of transpiration. It is these quantities that we require to know something definite about.

Experiments with the sugar cane to determine these quantities have been carried on by the writer at the Hawaiian Experiment Station. The specific purpose was to determine the volume of water required by the cane at different stages of its growth and to come at a rational mode of irrigation. The experiment was carried out as follows: Two tubs were used, having perforated bottoms, over which pieces of linen were laid to prevent the soil from going through or filling up the perforations. One hundred and twenty-five pounds of similar soil was put into each tub. The tubs were then set into galvanized-iron pans containing water. The water was kept up to a certain level, which level was slightly above the point of contact between the soil in the tubs and the water in the pans. The pans were carefully covered with moisture-proof oilcloth to prevent any escape of water excepting through the tubs. The volume of water taken up by the soil in the tubs and given off was daily measured and recorded and an equal volume restored to the pans. The volume of water that the soil could absorb and contain—that is, the measure of its absorptive power—was 48.2 per cent. of its own weight. In tub No. 2 three pieces of sugar cane were planted when the experiment was begun, and nothing in tub No. 1, after which the water given off by each tub was daily recorded for the following six months. During the first twenty-six days the two tubs gave off like volumes of water, each one evaporating during that period 14,220 grams, or 31 pounds. After the twenty-sixth day tub No. 2, in which the cane was planted, began to give off more than tub No. 1, containing soil only. At the end of seven months the relative volumes of water given off by the tubs were:

	Grams.
Tub No. 2	159,550
Tub No. 1	80,240
Difference	79,310

The water transpired by the growing cane during the period stated was thus 79,310 grams, or 174.5 pounds, and was distributed as follows:

Water transpired by sugar cane.

Time of observation	Age of cane. Months.	Transpiration. Grams.	Time of observation.	Age of cane. Months.	Transpiration. Grams.
May	1	860	August	4	19,800
June	2	6,500	September	5	20,050
July	3	11,000	October	6	21,100

From these data we learn the weight of water evaporated per given weight of soil during a given period of time. More important, we also see the volume of water transpired by the growing cane during the several months of its growth. We note the increasing volume required by the cane during the stages of growth and increase in bulk, and these observations are a clear and definite indication of the amount of water required in irrigation. When the cane plant is young its needs are small in comparison with its requirements at later stages of growth, and to apply the same volume during the early months that is demanded later is not only sheer waste, but entails damage to the young cane and loss to the soil. However, as explained later, the increased evaporation from the soil while the plants are too small to shade the soil to any extent in a measure counterbalances the decreased transpiration in this stage.

The weight of the cane grown in tub No. 2 by the consumption of 79,310 grams of water was 568.9 grams of water-free material, consisting of roots, 31.8 grams; stems, 53.9 grams; leaves, 483.2 grams. These figures show that in order to form 1 pound of water-free substance the cane organism transpired 147.8 pounds of water.

Attention is due to the behavior of the transpiring plant under the influence of given physical conditions. It was previously shown that the evaporation of water from soil and water surfaces was relatively very small in the absence of wind and during hot, sultry weather. This was by no means the case with the cane plants, as the following figures show:

Effect of weather conditions on evaporation from the soil and transpiration by sugar cane.

Date.	Number of days.	Character of wind.	Evaporation from soil. Grams.	Transpiration from plant. Grams.
June 10 to 23..............	14	NE. trade	5,700	1,550
June 23 to July 7..........	14	SSE. calm	3,200	3,300

These results were secured while the cane was still very young and the transpiration small. Similar results were observed repeatedly during the period of the plants' growth. The explanation lies in the fact that, although the hot, sultry weather, which obtains during the prevalence of the south wind has but a small effect upon water evaporation, it provides the physical conditions conducive to rapid plant growth. With the increased plant growth follows the vastly increased transpiration.

At this place may be stated the action of certain chemical elements upon the rate and volume of transpiration by the cane. On September 20 it was noted that the cane in tub No. 2 was looking yellow and in a reduced state of growth, and that the daily volume of water transpired had very largely fallen off. This change was believed to be due to want of available nitrogen in the soil, it having been shown by previous analysis that, while all other required elements were present in abundance, the nitrogen content was unusually small. Consequently nitrogen, in the form of nitrate of soda, was dissolved in the water that was being absorbed by the cane. On September 24 the cane was transpiring only 500 grams of water daily. Two days after the addition of the nitrogen to the water the leaves began to take on a vigorous appearance again and the volume of water transpired increased until it became more than double on the sixth day, when the cane stood up in full vigor and the yellow color was giving way to a deep green. At the end of October the transpiration fell off again, running down to only 400 grams daily, when a second quantity of nitrate of soda was put in the water. The result was practically the same as in the first test. The following table gives the details of the two tests:

Effect of nitrate of soda on transpiration of moisture by plants.

First test. Date.	Transpiration. Grams.	Second test. Date.	Transpiration. Grams.
September 24	500	October 31	400
September 25	600	November 1	600
September 26	700	November 2	700
September 27	900	November 3	700
September 28	1,200	November 4	700
September 29	1,100	November 5	800
September 30	900	November 6	800
October 1	900	November 7	800
October 2	900	November 8	800
October 3	900	November 9	800

These tests not only display the part played by the element nitrogen in the plants' growth and the consequent transpiration of moisture, but they also afford a clear illustration of the relations of fertilization to irrigation—relations which should receive the most careful consideration in all field work. In time of prolonged drought in districts of small or irregular rainfall the application of fertilizers that stimulate growth and transpiration is not advisable, since such agents cause a rapid exhaustion of soil moisture, after which the crop goes back again, its condition being finally worse than had it not been fertilized. But after a rain following a period of drought nitrogen should be applied at once to help the crop recover lost time.

POWER OF SOILS TO ABSORB AND RETAIN MOISTURE.

It is now necessary to consider the properties of the soils themselves, and to note the nature and differences of those properties in different soils and the behavior of different soils in practical irrigation.

Before making any explanation of the causes attention is called to the fact of the great variation in the power of soils to absorb and retain moisture. In the discussion of this point conditions, examination, and results relating to the Hawaiian Islands only are considered, and particularly investigations which have had special reference to the irrigation of sugar cane in these islands. Instead of giving a lengthy and detailed description of the means by which such examinations are carried out, attention is called to an illustration (fig. 1) of the apparatus used in the work, which almost explains itself. The labeled cylinders are of a known weight and are filled with soils whose water contents are known and the weight of each is taken. The frame from which the cylinders

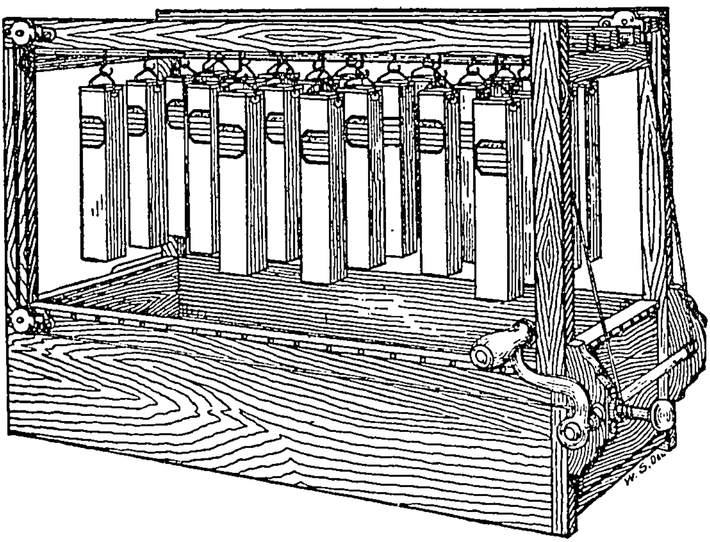


FIG. 1.—Apparatus used in observations on absorption and retention of moisture by soils.

are suspended is lowered until each cylinder is brought and kept in contact with the water in the trough below. When it is shown by repeated weighings that the respective soils have taken up all the water they can, the weights are recorded, and from these data are calculated their absorptive powers. The cylinders are then kept suspended in the air, the water is removed from the trough, and the cylinders are reweighed at weekly intervals, and from the data of the reweighing the retentive powers of the soils are ascertained.

The following table shows the results obtained. It should be understood that these soils are all of volcanic origin and that they owe their extreme divergencies in physical properties, in the first place, to causes which date from the emission of the lavas from the craters, and, in the second place, to the extreme variations of climatic conditions that exist locally upon these islands. The table expresses, in the second column, the percentage of water absorbed by each soil, in the third column the water retained at the end of one month, and in the fourth column the water finally retained:

Water absorbed and retained by Hawaiian soils.

Sample of soil.	Water absorbed.	Water retained at end of one month.	Water retained at final determination.
1	31.8	12.4	2.5
2	50.0	22.9	8.0
3	51.0	19.6	5.5
4	36.5	14.0	5.6
5	59.5	29.3	14.7
6	52.2	23.3	7.7
7	47.0	21.9	8.4
8	46.6	19.7	6.4
9	52.2	20.2	9.4
10	86.4	52.2	28.2
11	72.7	48.4	27.2
12	86.9	51.9	29.2
13	73.7	45.9	25.2
14	73.0	38.6	21.1
15	70.0	42.3	22.1
16	44.3	14.8	5.4
17	46.3	16.8	6.5
18	62.6	29.1	14.3
19	45.2	18.2	8.9

The last weighings were made five months from the beginnings of the tests. It was found that some, in fact most, of the soils were increasing again in weight with increasing dampness of the air in the room.

The causes of the extreme variations in those soils in the matter of their power to take up and hold water are several, but the chief one is the result of local climatic conditions. In localities having small rainfall the growth of vegetation is small, and consequently the amount of vegetable matter which comes from the decay of plants in the soil is also small. In wet districts the opposite is the case. Rainfall means vegetation and copious plant growth means excess of organic matter in the soil as a result of vegetable decay, and excess of organic matter also means an excess of nitrogen in the soil, the nitrogen being a constant component of living and decaying plant organisms. The relation of the amount of nitrogen in the soil to the power to absorb and retain water is shown by the following figures, which give the average of 100 analyses of Hawaiian soils:

Effect of nitrogen on moisture capacity of soils.

Soil samples.	Nitrogen content. Per ct.	Water absorbed. Per ct.	Water retained. Per ct.
Average of 50.............	0.163	44.6	6.2
Average of 50.............	.647	66.5	19.7

Following the action of organic matter ,the next most important factor in determining the power of soils to take up and hold water is the relative amount of clay, or of the elements which form clay, present in the soil.

For the purpose of this discussion we are less concerned with the causes than with the fact that great variations actually exist in the relative powers of soils to take up and hold water. This fact places before us a clear demonstration of the absolute need of first determining the absorptive power of each soil before the application of water.

SALTS IN HAWAIIAN SOILS AND WATERS.

Having considered some of the physical and physiological factors which affect the action and value of water in its relation to the production of crops, we proceed to matters bearing upon its use.

The waters of the Hawaiian Islands are of excellent quality, provided they do not come in contact with the sea inflow or with soils having high contents of salt, due to the overflow of the sea at some earlier period. In some localities, however. contamination by sea water has gone so far that the water is destructive to vegetable life. In most instances the deleterious agent is common salt; in others there is a mixture of common salt with chlorids of magnesium and calcium. The latter are most injurious to plant life and, in lowlands, lying almost level with the sea, where there are no means of getting these salts removed, their impregnation renders the soil useless.

A considerable portion of the water supply for irrigation in the Hawaiian Islands is derived from the underground flow. Ground waters, on account of the considerable proportions of certain highly desirable elements they contain, may be very valuable for application to crops. On the other hand, because of the large amount of substances inimical to plant life held in solution in some cases, they may be quite unfit for irrigation. Numerous instances of the unfitness of such waters for plant use are furnished by other countries, and special examples have been found by the writer upon the Hawaiian Islands.

The salt present in Hawaiian soils and its effect upon sugar cane are shown in the following table:

Salt found in Hawaiian sugar lands, and its effect upon sugar cane.

Samples of soil.	Location.	Salt in soil. Per ct.	Condition of cane.
1	Highlands	0.061	Normal.
2	do	.063	do
3	do	.050	do
4	do	.059	do
5	Lowlands	.129	Not wholly healthy.
6	do	.130	do
7	do	.155	Quite healthy and normal.
8	do	.181	Yellow in color.
9	do	.181	do
10	do	.460	Small, yellow, stunted.
11	do	.832	Cane white and dying.
12	Sea bluff land	.223	Leaves bleached, cane small.

In soils containing over 0.15 per cent. of salt, unless a liberal allowance of some vital element, such as nitrogen, is present to force on the growth, the sugar cane is liable to suffer. A further example is to hand showing the production of three parts of one field which contained different amounts of salt in the soil, the soil in other respects being identical:

Effect of salt upon the growth of sugar cane.

Field.	Salt in soil. Per ct.	Yield of sugar per acre. Tons.
First part	0.10	6.0
Second part	.45	1.5
Third part	1.00	0.0

But the salt content of the soil and its action upon the growing crop can be modified by the amount and quality of the water used in irrigation. "Sweet" water can carry the salt down out of reach of the cane roots, but if there is no outlet for the water through the subsoil it will come up again by evaporation to the surface, bringing with it a greater excess of salt to deposit near the roots. "Sweet" soil can bear the use of water containing a considerable amount of salt, but brackish water, added to a soil of appreciable salt content, acts suddenly and rigorously on the cane. An example of the great sensitiveness of the sugar cane, and the ease with which it takes up salt from irrigation waters, is shown in the following record of observations made by the writer:

Effect of salt upon sugar cane.

Condition of water.	Salt in waters. Per ct.	Salt in cane juice. Per ct.	Condition of cane.
Slightly brackish	0.125	0.470	Growing.
Highly brackish	.223	.714	Dying.

In this example the soils contained exactly the same quantities of salt, about 0.15 per cent., which is too high to come in contact with even the slightly brackish water without detriment to plants. The extreme sensitiveness, of the sugar cane to the salt content of waters is made very clear. From our present experience, the danger point should be placed at 0.14 per cent., or 100 grains of salt per imperial gallon.

The following table gives some analyses of Hawaiian waters that are in constant use for sugar-cane irrigation:

Analyses of Hawaiian waters.

Constituents.	Sample No. 1. Per ct.	Sample No. 2. Per ct.	Sample No. 3. Per ct.	Sample No. 4. Per ct.	Mean analysis of all Hawaiian streams and springs. Per ct.
Silica	0.0030	0.0076	0.0072	0.0026	0.0023
Iron oxid and alumina	.0015	.0006	.0004	.0006	.0005
Calcium oxid	.0015	.0076	.0043	.0012	.0015
Magnesium oxid	.0020	.0058	.0051	.0015	.0013
Potassium oxid	.0010	.0006	.0008	.0005	.0005
Sodium oxid	.0030	.0094	.0081	.0030	.0033
Chlorin	.0070	.0200	.0178	.0041	.0040
Sulphuric acid	.0002	.0033	.0027	.0012	.0011
Phosphoric acid	.0000	.0002	.0001	.0001	.0001
Total solids	.0260	.0760	.0600	.0190	.0200
Grains per gallon	18.4	53.5	42.4	13.3	13.6

Samples Nos. 2 and 3 were injuriously affected with salt to a slight degree. These samples were from wells at almost sea level and only a short distance back from the tide line. Waters have been analyzed which showed over 300 grains of salt per gallon, thus showing the infiltration of the sea water. The data that have been furnished demonstrates the primary importance of fully testing the qualities of waters drawn from sources near to the sea, and examples could be produced showing the enormous losses that have followed the ignoring of such tests.

DUTY OF WATER.

By the term "duty of water,"[1] as used in this bulletin, is understood the volume of water that is required to mature a given crop in given conditions of soil and climate. That the duty of water can not be a definite factor, the water being in equal demand and rendering the same service in all locations, has been amply indicated by the facts stated in preceding paragraphs. It has been shown that there are locations where the volume of water directly evaporated from the soil is double the amount removed in other locations and under totally different conditions of climatic exposure and action. Further, it was shown that soils themselves vary extremely in their powers to take up and retain moisture, which affords another illustration of the factors that determine the service of applied water in relation to the crop. If a given volume of water is applied to a soil of low absorptive capacity and with a small retentive power, loss occurs by seepage on the one hand and by extreme evaporation on the other, thus causing a large expenditure by the soil and a minimized service rendered to the crop. Again, crops may vary between very wide extremes in the volumes of water they consume per unit of substance formed, and consequently in the volumes necessary to bring them to maturity.

IRRIGATION PRACTICE ON THE HAWAIIAN ISLANDS.

The chief crops that are grown by the aid of artificial irrigation in Hawaii are rice and sugar cane.

The lands used for rice are the lowest flats found at the outlets of valleys and close on the sea. Irrigation is practiced upon all these lands, but no means of determining the volume used per acre have been adopted, and data are not at hand bearing on the question.

Sugar production is, relatively speaking, a recent matter so

[1] For definition of this term as used in the irrigation investigations of this Department, see U. S. Dept. Agr., Office of Experiment Stations Bul. 86, p. 33.

far as the present volume of production is concerned. So late even as 1880 the output is recorded as being 30,000 tons, while the production last year (1899) was 282,807 tons. The part played by artificial irrigation in the production of the Hawaiian crop is seen from the following statement:

	Tons.
Sugar grown by natural rainfall............	116,382
Sugar grown by irrigation	166,425

The area to which water is artifically applied is yearly increasing, and in two years more than two-thirds of the crop, which is also vastly increasing, will be grown by aid of irrigation.

The richest lands upon the islands are those lying toward and a little above sea level. In most of the districts, however, the rainfall over the low-lying lands, and especially upon the leeward side, is utterly insufficient to produce the sugar crop. Until the practice of irrigation was adopted these lowlands were useless, but now they are, beyond comparison, the richest and most productive.

The primary source of water upon the Hawaiian Islands is rainfall. Two unfavorable conditions attend its precipitation: (1) The maximum quantity falls during the cool season, when the crops are not in a state of maximum growth and able to make use of it, and (2) the chief precipitation is over the mountain areas, where the water falls, soaks down into the rock strata, and runs largely to the sea, unless arrested and returned to the land. An illustration of the variation of rainfall with altitude is afforded by the following table:

Variation of rainfall with elevation.

	Rainfall at Inches. sea level.	Rainfall at elevations of 2000-3000 feet (2½ miles Inches. from sea).
Honolulu (Oahu	32	118
Hana (Maui)............................	28	179

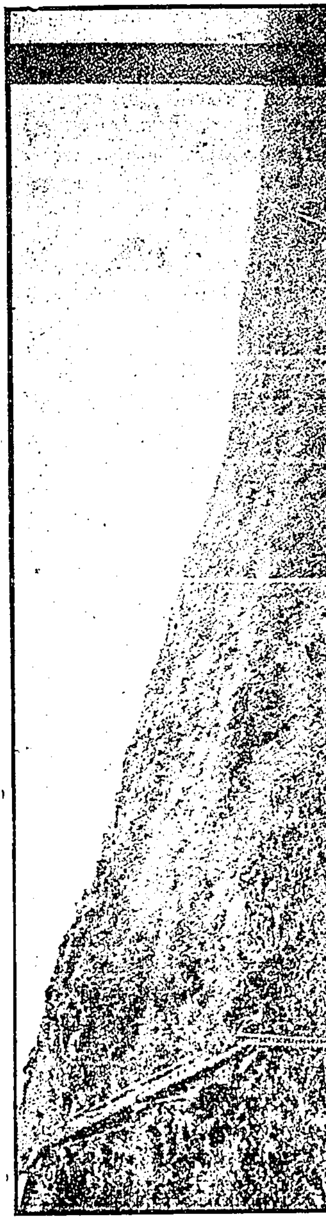
The apparently disadvantageous circumstance of heavy precipitation at maximum elevations has been turned into a special advantage by engineering means. In certain districts the water is collected by small ditches over the mountain areas, where it falls, and is conducted by main ditches or by flumes down to the cane-bearing lands below, over which it is distributed by gravity. Where the rainfall can not be easily collected over the mountain areas, the water which sinks down into deep substrata is tapped and arrested at or near sea level, where it is found running toward the sea. In places where the lava rock strata run out before reaching the sea the water comes to the surface in springs, but the great body flows out or is held in underground reservoirs at varying depths, and has to be sought for by means of wells, from which the water is lifted and forced up to considerable elevations by high-duty pumps, where it is distributed.

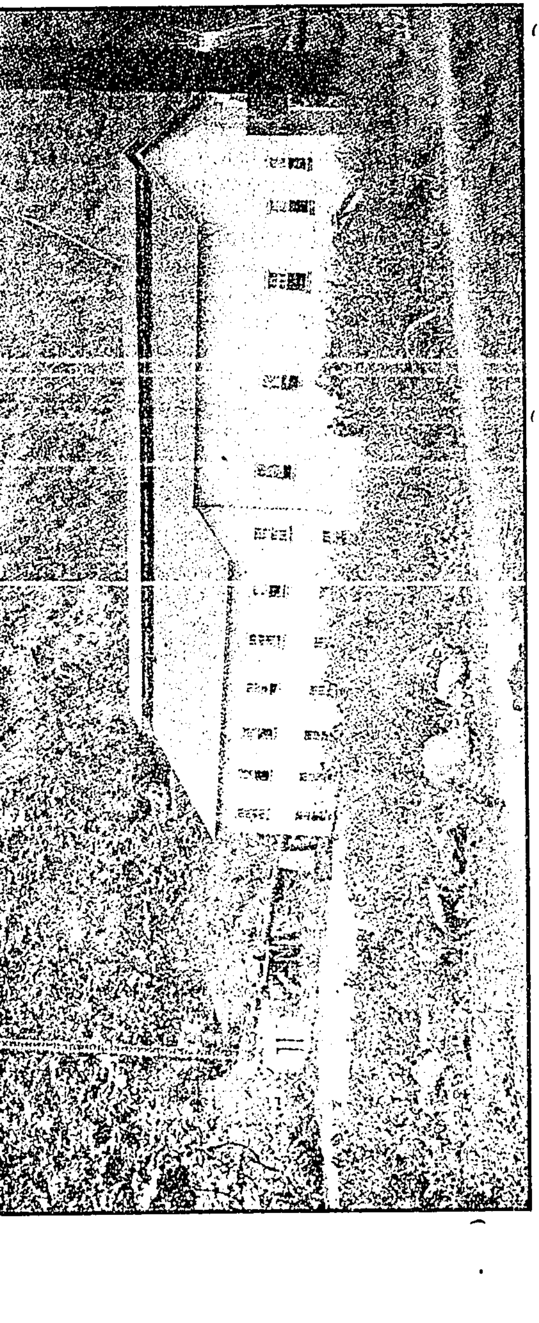
The pumps that are in service on the islands are chiefly of American build, and are in some instances of large capacity. Their duties range from the small lifts of the centrifugal pumps to those raising 12,000,000 gallons per 24 hours. (Pls. I and II.)

The amount of water applied in the irrigation of Hawaiian sugar cane is controlled mainly by the volume of the supply. Concerning the volume that is considered necessary and that is taken as a basis of estimation in calculating the water required by any given plantation and the capacity of the pumps necessary to lift and apply it, reference is had to the data contained in a report on investigations made in 1889 by Messrs. J. D. Schuyler and G. F. Allardt, civil engineers.[1] The data and the views contained in that report were made the basis of operations by the authorities quoted, and they are still the views and represent the practice of those men who were on plantations at the time of the publication of the report in 1889. Other views and other methods are now coming into practice which are based more largely upon the principles set forth in the earlier paragraphs of this report and upon results obtained in actual experiments in irrigation. These will be spoken of later. The report referred to says:

"It seems to be the general practice here (Island of Oahu) to irrigate 'plant' cane every three or four days for the first month after planting or until it has made a strong growth of root and stalk. After that a watering is given every seven days for a time, diminishing to one watering every ten days, which is continued for about fifteen months from the time of planting, or until the maturity of the cane. It is customary to cease irrigation from one to three months before cutting. If, as in some districts, the cane did not mature short of eighteen to twenty months from time of planting, the period of irrigation would be from fifteen to eighteen months. In making our estimate we have assumed that fifteen months of irrigation would be the average required for sugar cane on the leeward slopes of this island (Oahu). Three waterings per month is the least that is considered safe to apply to keep the cane

[1] "Water supply for irrigation on the Honouliuli and Kahuku ranchos," Oakland Cal., 1889, pp. 32; see also Special Consular Reports on Canals and Irrigation in Foreign Countries, 1891, pp. 395-407.





EXTERIOR VIEW OF A PUMPING STATION IN HAWAII.

The large pipe which conveys the water from the pumps to the fields is shown mounting the side of the gulch in which the station is located.

growing without check. In localities corresponding in position and climate to Honouliuli it is customary to maintain this periodical irrigation regardless of the rainfall. The rain may at times exceed the quantity applied artificially, but irrigation is performed as usual notwithstanding, in order that there shall be no break in the waterings. It seems to be generally understood by all planters that the depth of each watering shall be at least an average of 3 to 4 inches over the whole surface. Where the intervals between waterings are ten days and the depth applied is 4 inches, 1 cubic foot of water per second will perform a duty of 59.5 acres. With intervals of seven days and the same depth of water applied, 1 cubic foot per second would irrigate but 41.6 acres, or 55.5 acres if the depth applied is but 3 inches."

At this place it may be convenient to state, for the use of persons who judge by the standard of rainfall. that 1 cubic foot of water per second is equal to a flow of 294,700,032 United States gallons in fifteen months, and that if this volume were applied to 41.6 acres that would be equal to 7,108,173 gallons per acre, or a rainfall of 210 inches per year and 262 inches to mature the crop.

The report proceeds to give examples, and begins with the Hawaiian Commercial Company's plantation at Spreckelsville, Island of Maui, of which it says:

"The record for the calendar year 1888 shows that there was delivered to the plantation the following quantity of water:

	Cubic feet.
From the Haiku ditch	1,175,000,000
From the Waihee ditch	919,000,000
Total	2,094,000,000

Or 15,700,000,000 gallons. The rainfall during this period was 19.08 inches.

"With this water there were irrigated 2,000 acres of 'plant cane' and 600 acres of 'ratoons' (volunteer second crop). In addition, 400 acres of seed cane were irrigated once a month, consuming a quantity roughly estimated at 70,000,000 cubic feet. The remaining 2,024,000,000 cubic feet would be equivalent to a constant average flow through the year of 64.18 cubic feet per second, which, divided into 2,600 acres, would appear to give an average duty of 40.5 acres per cubic foot per second. and to indicate that the mean depth applied was nearly 18 feet in the aggregate (22 feet, or 264 inches, for the crop period of fifteen months)."

The report states that the explanation for "this seemingly low duty" may be found in the fact that the water was also used for cattle, domestic, and other purposes.

Mr. Hugh Morrison, general manager of the plantation at Spreckelsville, states, as an epitome of his experience, that 11,000 cubic feet per acre applied every seven days will produce the very best results in growing sugar cane. Covering the period of fifteen months already stated, that amount was equal to 5,348,200 gallons per acre, or a rainfall of 197 inches, which with the 19.08 inches of actual rainfall makes a total of 216.08 inches to produce the crop. The report continues:

"Mr. Morrison further adds that it is almost impossible to put on too much water (of course within reasonable limits), and that the more water is applied, without going to extremes, the greater the yields. He has obtained a yield as high as 10 tons of sugar per acre in localities sheltered from the wind. The average yield of 1888 on 2,000 acres of plant cane was $5\frac{3}{4}$ tons of sugar per acre; the ratoon crop averaged $3\frac{1}{3}$ tons per acre. * * * *

"On the Wailuku plantation, Island of Maui, where the water supply is very abundant and in excess of the needs of the plantation, the consumption is equal to a duty of about 50 acres per cubic foot per second on plant cane and 60 acres on ratoons.

"On the Hamakuapoko plantation, Maui, where the average annual rainfall is reported as 35.2 inches, the amount applied is stated by the superintendent, Mr. James Cowan, to be 10,890 cubic feet per acre to each watering. The intervals between waterings are seven days, and consequently the duty of water in continuous flow is 55.5 acres per cubic foot per second."

This amount is equal to a depth of 195 inches, which, with the natural fall of 35.2 inches of rain, is equivalent to a total rainfall of 230.2 inches to mature the crop, or 184.2 inches per annum. Continuing, the report says:

"In making up these figures, however, Mr. Cowan qualified them by saying that they are for the full capacity of the ditch, which is not always full when required, and is only partially compensated for full flow by the rainfall. * * * The average yield of the plantation is given at 5.6 tons of sugar per acre for plant cane and 4 tons for ratoon crop. * * * He summarizes by stating that to raise 1 pound of sugar requires about 51.8 cubic feet of water."

There are so many elements of uncertainty included within the foregoing statement that it must be considered as merely an approximation to the truth. The report further states:

"On the Kekaha plantation, Kauai, water is obtained by pumping to a height of 18 to 36 feet, an average of about 27 feet. The delivery of the water is contracted for at the rate of $35 per acre per annum. The contractor is required to deliver sufficient water to irrigate 700 acres every ten days to an average depth of 4 inches at each watering. The duty thus performed, presuming the quantity contracted for is fully delivered, would be 59½ acres per cubic foot per second. The pumping is done during ten hours each day. The three pumps require to have a capacity of 7,000,000 gallons per day each. Coal cost $14[1] per ton at the pumps. A very unusual yield is reported from this plantation. Ratoon crops for seven consecutive years are said to have produced an average of 5 tons of sugar per acre each year."

In summing up their observations, Messrs. Schuyler and Allardt say that a greater duty than 60 acres per cubic foot per second can not possibly be considered safe; or in other words, at least 5,000,000 gallons per acre are required to make the crop.

The data and conclusions furnished by Schuyler and Allardt have been given at length, for the reason that they formed the basis of computations some ten years ago and are still followed by the older plantation authorities. During the past six months two persons who are connected with the opening up of new plantations assured the writer that those estimates "were not conservative enough to be safe, and that in their calculations and provisions they were providing for not less than 6,000,000 gallons of water per acre for the crop." The more conservative estimates of those gentlemen are not based upon any ascertained knowledge of the requirements of the soil and crop. They are merely the result of a wish to be safe. As a consequence, when the basis of 6,000,000 gallons per acre for the crop becomes the practice, some other gentlemen of conservative mind who also wish to be safe will appear who will think 7,000,000 gallons a necessary provision. At present the practice upon the plantations is not resting upon ascertained requirements which can be arrived at only by the aid of a knowledge of the physical laws that have been set forth and by actual tests involving the determination of the amount of water that the crop during the different stages of growth requires in given conditions of soil and climate.

STUDY OF IRRIGATION AT THE HAWAIIAN EXPERIMENT STATION.

In view of the absence of established data bearing upon the actual requirement of the sugar cane in the conditions of soil and climate of the Hawaiian Islands, and also on account of the great variations that obtain in the practice of irrigation, the writer determined upon a series of tests which should be carried out along lines of strictly economic purpose, but controlled by the aid of such physical and chemical observations as were previously shown to underlie any system of rational irrigation.

[1] It now costs $10 per ton.

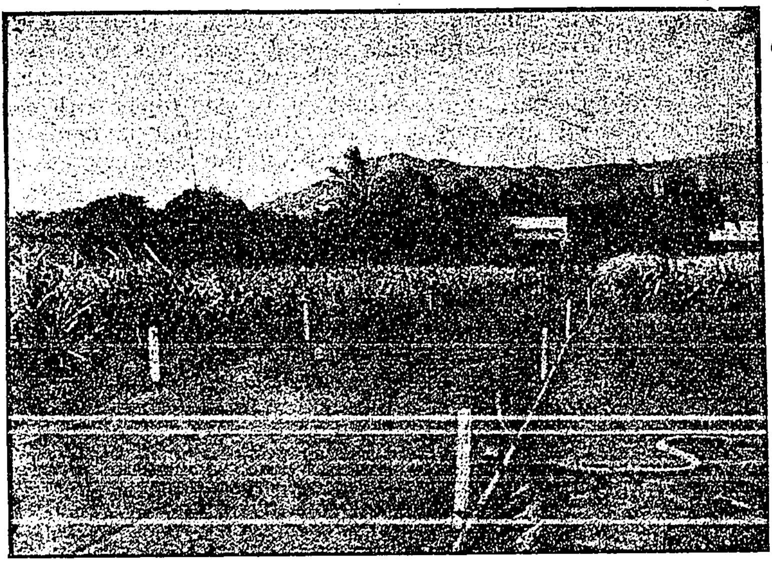


Fig. 1—ARRANGEMENT FOR IRRIGATING PLATS AT THE HAWAIIAN EXPERIMENT STATION.

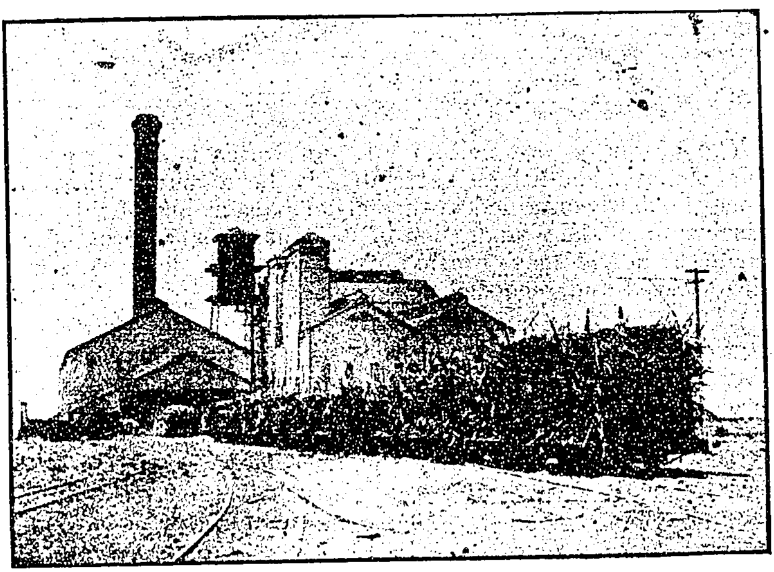


Fig. 2. A SUGAR FACTORY IN HAWAII.

The Hawaiian Experiment Station is located in the suburbs of Honolulu and comprises 5 acres of land. In laying out the area into divisions and plats special provisions were made for the use of irrigation water. The water supply is that of the city municipality, and it is laid on by iron pipes with very numerous faucet discharges. The distribution is made by means of rubber hose, thus controlling the delivery at any place or time. (Pl. III.)

The topography of the field is favorable for irrigation, its surface being relatively level.

The soil is exclusively derived from the decomposition of basaltic lavas. There is a depth of 15 inches of tillable earth resting upon a porous subsoil, an understratum which is composed of chips of lava stone, scoria, and black sand. The total mass of soil is thus relatively small, 1 acre to the depth of 15 inches weighing 4,368,825 pounds. The constituents of the soil are shown in the following table:

Analysis of soils at Hawaiian Experiment Station.

Soil constituents.	Amounts present. Per ct.	Soil constituents.	Amounts present. Per ct.
Moisture	9.526	Ferrous oxid	5.515
Combustible matter	9.347	Alumina	12.540
Insoluble silica	15,660	Manganese oxid	.145
Soluble silica	17,058	Lime	.861
Titanic acid (TiO^2)	2,460	Magnesia	.821
Phosphoric acid	1,050	Soda	.175
Sulphuric acid	.164	Potash	.581
Carbonic dioxid	.080	Nitrogen	.149
Chlorin	Trace		
Ferric oxid	23.630	Total	99.862

The power of this soil to take up water is 48.5 per cent. The climatic conditions have already been amply discussed, since the data contained in the earlier paragraphs of this work bearing upon the evaporation of moisture from water and soil surfaces and the transpiration of water by the sugar cane were all observed and recorded at this station.

By the mode of applying water in use at the Experiment Station every gallon of water that goes onto each experimental plat is measured and recorded. This exactness is absolutely necessary not only in order to note the action of the water, but also that of other factors upon the development and results of the crop. Consequently the records of rainfall and the measurement of the water applied furnish the total water at the disposal of the crop in the course of its growth.

Two crops of cane have already been grown upon the Experiment Station grounds by the aid of irrigation. The first crop was planted in July, 1897, and harvested 20 months later. The second crop was planted late in June, 1898, and is now being taken off (March, 1900). The period of irrigation, however, extended from the time of planting until November of the following year, making some 17 months during which water was applied. Unless the weather is extremely dry, the cane does not receive water several weeks previous to its being cut, in order to induce a more thorough ripening. Excess of moisture operates to keep the cane immature and induces new shoots to appear and grow, thus injuring the crop.

In the following table are recorded the amounts of water the crops received during the years specified as rainfall and by irrigation:

Amounts of water received by crops at Hawaiian Experiment Station.

Month.	1897-98. Inches. Rainfall.	Inches Irrigation.	1898-99. Inches. Rainfall.	Inches. Irrigation.
July	0.63	3.0	0.94	4.0
August	1.02	3.0	1.58	4.0
September	4.12	1.5	.88	4.0
October	2.07	3.5	1.75	3.0
November	2.11	2.0	1.32	3.0
December	.88	3.5	1.86	2.0
January	6.18	0.0	1.00	4.0
February	8.04	1.0	3.75	1.5
March	10.39	0.0	3.98	3.0
April	1.21	1.0	.85	4.0
May	.84	4.5	2.01	4.0
June	2.60	2.0	.88	7.0
July	.94	5.0	.17	7.0
August	1.58	5.5	1.90	9.0
September	.88	6.5	.75	8.0
October	1.75	4.5	2.92	6.0
November	1.32	1.0	.47	3.0
Total	46.56	48.0	26.01	76.5

From the data in the rainfall columns it is seen that the most of the rain falls during the cooler months of the year, which are the months of minimum plant growth. This is a special climatic drawback. The most advantageous combination of climatic conditions is the concurrence of high temperature and maximum rainfall, or a moist, hot season, and a dry, cool season, which combination occurs in the sugar zone of Queensland. It is very apparent that water does not possess a maximum value if it falls during the cool season and when the crop is not in full growth and able to make use of it. For this reason a less value and importance have to be ascribed to the rainfall of these islands than might otherwise be.

The table shows that, during the years 1898 and 1899, the rainfall covering the period of seventeen months was only 26.01 inches, or 18.3 inches per annum. It should also be understood that the extra deficiency in the rainfall can not be measured by the simple amount of that deficiency, for the reason that, instead of the cloudy, wet days when the rain should have fallen, dry days of high evaporation occurred, thus aggravating the natural situation and causing a greater need for the water supplied by artificial means. When the totals of the data contained in the table are brought together, it is seen, however, that the differences in the total amounts of water consumed by the respective crops are not material and no greater than has been reasonably accounted for.

Total water received by two crops of sugar cane.

Crop period.	Rainfall. Inches.	Irrigation. Inches.	Total. Inches
1897-98	46.56	48	94.56
1898-99	26.01	77	103.01

Before proceeding to furnish the full results of the two crops attention may be called to the comparative value of the water which fell as rainfall and that of the water applied in irrigation, taking the sugar equivalent as the expression of value. It is possible to do this by the use of data obtained during the season 1897-98, when tests were carried out in the experiment field under identical conditions of soil, cultivation, and fertilization. In these tests twenty plats of cane were grown by the aid of irrigation in addition to the rainfall, and eight tests were made without any irrigation (Pl. IV), the results being as follows:

Yield of irrigated and unirrigated cane.

No. of tests.	Rainfall.	Irrigation.	Yield sugar per acre.
	Inches.	Inches.	Pounds.
20	46.56	48	24,755
8	46.56	..	1,600
Difference in favor of irrigation	....	..	23,155

Nothing could show more conclusively than these figures the necessity of irrigation under the existing conditions, and the enormous sugar-equivalent value of irrigation water applied systematically to the cane during the season of maximum growth, which is the summer season. An equal volume of water falling in heavy rains during the cool season, when growth is slow, is largely lost through percolation and produces a comparatively small value in sugar.

The following tables contain a statement of the crops of 1897-98 and 1898-99 and of the value of the water applied by

IRRIGATED AND UNIRRIGATED CANE AT THE HAWAIIAN EXPERIMENT STATION.

irrigation. A brief table is first given showing the average weight of cane and yields of sugar for the two seasons:

Yield of cane and sugar at Hawaiian Experiment Station.

Crop period.	Number of tests.	Yield of cane per acre. Pounds.	Yield of sugar per acre. Pounds.
1897-98	20	166,562	24,755
1898-99	15	192,440	27,133

These are the results in cane and sugar per acre of crops that were about nineteen months on the ground and subject to systematic irrigation for seventeen months.

The relation of the crops to the total volume of water received both as rainfall and by irrigation is as follows:

Water required to produce 1 pound of sugar.

Crop period.	Rainfall. Inches.	Irrigation. Inches.	Water per acre. Gallons.	Yield of sugar per acre. Pounds.	Water required to produce 1 pound of sugar. Pounds.
1897-98	46.56	48	2,567,682	24,755	865
1898-99	26.01	77	2,797,133	27,133	859

The volumes of water consumed by the cane per pound of sugar made during the growth of the two crops are very nearly the same. During the growth of the crop of 1897-98 some of the rainfall occurred in heavy precipitations, and it was ascertained that water escaped through the subsoil and was lost. During the production of the crop of 1898-99 none of the water received, either from rainfall or from irrigation, was lost in this manner. No single rainfall exceeded 1 inch, and in irrigating no more than 1 inch of water was applied at any single watering.

It is seen from the preceding tables that the maximum quantity of water applied artificially during the season of extreme drought was 77 inches during a period of seventeen months, or 2,090,858 gallons of water per acre, to make a crop containing 27,133 pounds of pure sugar per acre. These results are the average of fifteen tests, which were made under identical conditions of soil, cultivation, and fertilization.

The following table brings together the estimates of the duty of water in the Hawaiian Islands contained in the report of Schuyler and Allardt,[1] previously referred to, and the results of experiments made at the Hawaiian Experiment Station by the writer:

Duty of water in Hawaiian Islands.

	Water applied per acre per crop		Yield of sugar per acre.	Water required to produce 1 pound of sugar.
	Depth.	Quantity.		
According to Schuyler and Allardt:				
	Inches.	Gallons.	Pounds.	Pounds.
Spreckelsville (1)......	262.00	7,114,348	11,100	5,345
Spreckelsville (2)......	216.00	5,865,264	11,100	4,407
Hamakuapoko	230.20	6,250,850	11,300	4,613
Kekaha	198.20	5,381,428	12,000	3,740
At the experiment station:				
First crop (1897-98)....	94.56	2,567,682	24,755	865
Second crop (1898-99)..	103.01	2,797,133	27,133	859

In the above table the yields of sugar per acre as given are higher than stated by the plantation authorities. For Spreckelsville the yields as stated were "for plant cane, 5.75 tons of sugar per acre; the ratoon crop, 3⅓ tons per acre;" for Hamakuapoko, "5.6 tons of sugar per acre for plant cane and 4 tons for ratoon crops," and for ratoon crops at Kekaha "5 tons of sugar per acre for seven years." These figures express the amounts of sugar per acre obtained by the mills and marketed, and not the full amounts produced by the soil. As a correction, and to make the figures comparable with the statement of experiment-station yields, 20 per cent. has been added to the amounts given by the plantations. This may be rather too much, but it has to be remembered that the mills ten years ago did not obtain as much sugar from the cane as they do today. However, the figures of yield as given are probably a little in favor of the plantations.

In comparing the data contained in the table it is again to be remembered that the figures furnished by the plantations state what was actually being done by those plantations. The experiment-station data show what has been done and what it is possible to do, where the irrigation is carried out according to scientific principles and where the conditions are under control. Upon a large plantation the conditions can not be controlled to the same extent as is possible with experiments on limited areas. This in no wise lessons the force of the fact that plantations are wasting huge volumes of water in their practice of irrigation or removes the necessity of examining into and determining the location and causes of the waste.

The figures contained in the last column of the table show the founds of water received from rainfall and irrigation per pound of sugar grown. Instead of using sugar as the stand-

[1] Special Consular Reports on Canals and Irrigation in Foreign Countries, 1891, pp. 396-398.

ard we may use the total dry substance of the crops in its relation to the water received per acre. The exact data furnished by the station's experiments enable this to be done:

Water used to produce 1 pound of dry substance.

Crop period.	Water received per acre. Pounds.	Dry substance produced per acre.[1] Pounds.	Water required to produce 1 pound of dry substance. Pounds.
1897-98	21,414,457	98,725	216
1898-99	23,328,089	110,087	212

The most fertile plantation upon the Hawaiian Islands last year yielded 20,500 pounds of sugar per acre, and, according to the estimate of the manager, consumed a little over 5,000,000 gallons of water per acre. On this plantation a less volume of water produced double the quantity of sugar that was obtained at Spreckelsville and Hamakuapoko; consequently the waste of water at those places must have been great. Upon this fertile plantation, however, there are ample evidences of past excessive irrigation and waste. The volume of water used per acre was double that used at the experiment station to produce less sugar per acre.

A small crop of say 30 tons of cane or 4 tons of sugar per acre can not in its growth consume the volume of water demanded by a crop of 80 tons of cane or 10 tons of sugar per acre. It can consume only a fixed portion of that volume. The same principle applies in the demands made upon the soil for plant food. The large crop absorbs more of the soil constituents to compose its substance and promote its growth. Water is only one of the essential factors which control the size of the cane or other crop. The depth and fertility of the soil, the fertilizing elements supplied, and the extent of cultivation are all potent factors affecting production. It has already been shown in a previous paragraph that the growth of the cane and the amount of water used during increased growth, as indicated by the increased transpiration of water by the cane, are very noticeably influenced by the action of nitrogenous fertilizers.

[To be continued.]

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[1] By "dry substance produced per acre" is meant the total amounts of water-free cane and leaves produced by 1 acre of ground. During the crop period 1897-98 some rainfall water was lost by percolation through the subsoil, but how much was not ascertained. During the growth of the crop of 1898-99 no water was lost. Two hundred and twelve pounds of water were used, therefore, to produce a pound of dry substance.

SUGAR TAX AND SUGAR PRICES IN THE UNITED KINGDOM.

(From United States Consul Mahin, Nottingham, England.)

A topic of lively discussion in the United Kingdom is the rise in the price of sugar. The following table of prices shows the retail advance in a year in the grades of sugar most commonly used:

Price of sugar in England in February, 1904 and 1905, per pounds.

Kind.	February, 1904. Cents.	February, 1905. Cents.
Lump	4 to 5	6 to 7
Granulated	3½ to 4	5½ to 6
Castor	4½ to 5	6 to 7
Demerara	4 to 5	6 to 7

It is believed that prices will still further advance—at any rate, till the acreage of beet sowing in April is known. If the acreage should be very great, prices are then expected to decline.

The cause of the increased prices is variously assigned and is the subject of much discussion. The chief wholesale grocery firm here attributes the increase to larger consumption on the Continent and to the dry summer of 1904, which prevented the beet from swelling, thus causing very small roots. Another firm indicates speculation as an important element.

The opponents of the present government attribute the advance to the provisions of the Brussels sugar convention in 1902, coupled with the duty on sugar imported into this country, amounting to 4s. 2d. per hundredweight ($1.01 per 112 pounds), equivalent to a little more than nine-tenths of a cent a pound. Under the terms of the Brussels convention, Great Britain cannot import sugar from certain countries not joining in the convention—Russia, for instance, in late years second to Germany only in production of sugar and a former source of supply for the United Kingdom. The government is bitterly denounced by the opposition, and by some grocers and confectioners, for abetting or consenting to such restriction, since, as is alleged, no countries joining in the convention could make up to Great Britain the shortage of sugar caused by the prohibition against buying from Russia. Opposed thereto, however, is the assertion that the imports from such countries averaged the immaterial amount of only about 30,000 tons in the total import of 1,500,000 tons of sugar per year, a proportion relatively so small as to have no effect on prices. Furthermore, it is pointed out, Russia shared in the 1904 shortage, and now has no sugar to export.

The sugar tax imposed in 1901 is also denounced by the opposition as a war tax and also on general principles, and more grocers and confectioners petition for its repeal than condemn the provisions of the sugar convention. That is to say, the objections to the convention's provisions are mainly political, while opposition to the sugar tax is not only political but is also widespread, for commercial reasons, among friends of the government.

The convention, its defenders declare, had no influence on the price of sugar, unless to lower it; for it appears that prices were lower for some months after the convention (signed in March, 1902) took effect, in September, 1903, and that there was no material advance in prices for about a year afterwards. They charge the advance wholly to the short Continental beet crop in 1904—the shortage being, by the latest estimate, 1,180,000 tons. This was offset by an increase of 400,000 tons in cane sugar (mostly West Indian), which was not, however, sufficient to hold down prices. It is claimed that this increase was a direct result of the abolition of sugar bounties by the Brussels convention, and that the stimulus thus given to the colonies will this year and in following years greatly enlarge the area of cane growing. It is even asserted that without abolition of the bounties the cane-growing industry will have been virtually ruined. Summing up, the government's friends contend that but for the convention prices would be even higher than they are now.

As to the influence of the duty on sugar, its defenders point out that the price in this country was more in 1900 before the duty was imposed, and in 1901, when it took effect, than in 1902, when the tax was being collected. In 1903 the price rose but was still less than before the tax was levied; and this was also true of even 1904. No one seriously contends, however, that the removal of the duty would not reduce the present price of sugar; for as none is produced on these islands, they can not offer that wholesome competition which compels the foreign exporter to pay, indirectly, at least a part of the import duty.

The government has been petitioned by associations of grocers, confectioners, and other trades people to repeal the sugar duty, but replies in each case that it can not spare the £6,000,000 ($29,199,000) from its revenues. It points out also that the duty was not imposed as a war tax, but, as explained by the chancellor of the exchequer at the time, was necessary to meet an increase in ordinary public expenditure.

But whatever the cause of the increased price of sugar, it is evidently a great hardship to various industries. Confectioners and mineral water manufacturers in particular seem to be severe sufferers. It is claimed that the employees of industries using sugar as raw material number 12,000 less now than before the sugar tax was imposed and that shorter working time affects 50,000 more. In this city the number of confectioners' employees is reduced some 200. One large London confectionery concern claims that annual profits of about $100,000 before the sugar duty was imposed have dwindled away to an actual loss of nearly $10,000 in 1904. Another similar concern in the midlands says it has paid no dividend since 1901 and declares that the tax has reduced its "turnover" more than $250,000 a year, besides compelling it to pay thousands of pounds in duty on the sugar it used. It is averred that the only confectionery manufactories now in existence have been saved by their strong financial position, and that, generally speaking all industries dependent upon sugar are being "throttled."

The president of the National Union of Mineral Water Manufacturers says that his trade is suffering as much as that of confectionery; that the 3,000 manufacturers of mineral water in the kingdom employ, in normal times, 200,000 workers; that many factories are now closed, and that in others the working force has been reduced and wages cut. The total number of hands thrown out of work is not stated.

The manufacture of jam, which is a great industry in this country, is also asserted to be disastrously affected, but I have not yet learned any details.

Besides the actual loss of profit and employment in British manufactories, it is stated that Continental makers of sugar products are now able, by reason of the lower cost of the raw material to them, to flood the British markets with their goods and crowd out what is left of the home article; and that for the same reason former export markets are now closed to the British product.

Added to all this the inevitable reduction of sugar consumption by the masses of the people will, it is prophesied, lead to physical degeneration.

The British Federation of Confectioners' Association resolved at Hull, on January 20, to ask members and customers to vote, at the next parliamentary election, for only such candidates as will support abolition of the sugar tax. So politically potent in fact is this question apparently becoming that it might be the deciding factor at the election. The success of the Liberal candidate at the recent by-election in North Dorset, where previously there was an ample Conservative majority, and where the sugar question was pushed to the front by his supporters, is referred to as indicating public sentiment.

A new monthly journal has been started to help the movement for untaxed sugar.

Another phase of the situation is renewed activity in the promotion of sugar-beet growing in this country. Among recent experiments, it is announced that the agricultural college at Kilmarnock, Scotland, has succeeded in growing a large crop of sugar beets; that the yield is fully up to the Continental average, and that the roots give double the quantity of sugar that the German beet does. The experimenters advise Scotch farmers to grow sugar beets, and suggest the establishment of sugar factories in the west of Scotland.

FRANK W. MAHIN, *Consul.*

NOTTINGHAM, ENGLAND, February 1, 1905.